Observational and modeling case study of an extreme atmospheric forced event in the Turkish Straits on Nov. 22, 2008

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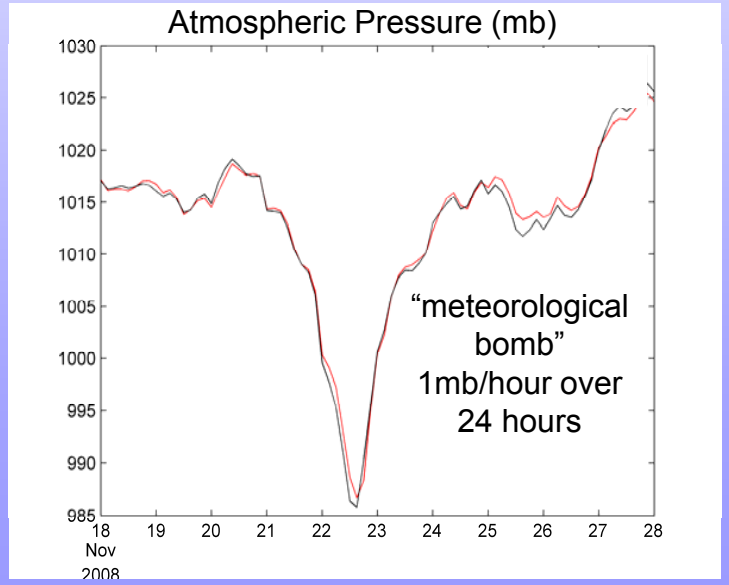
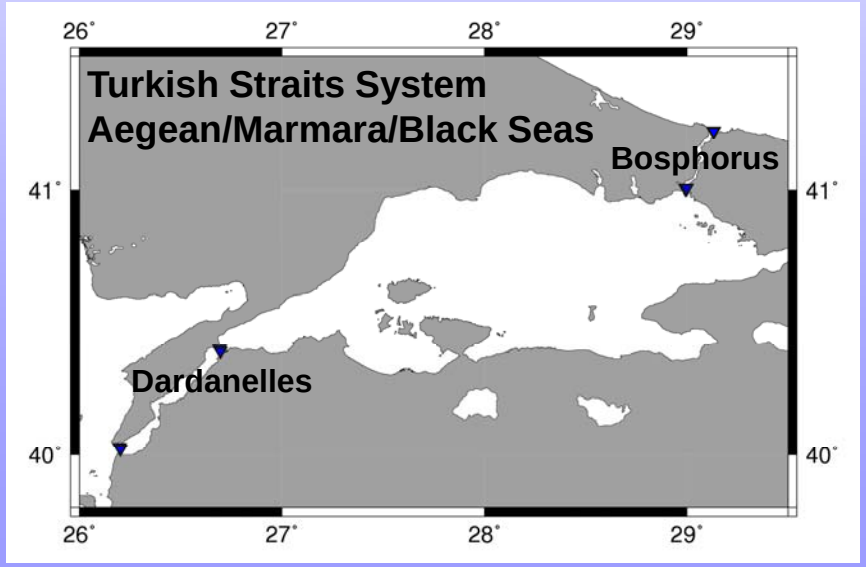
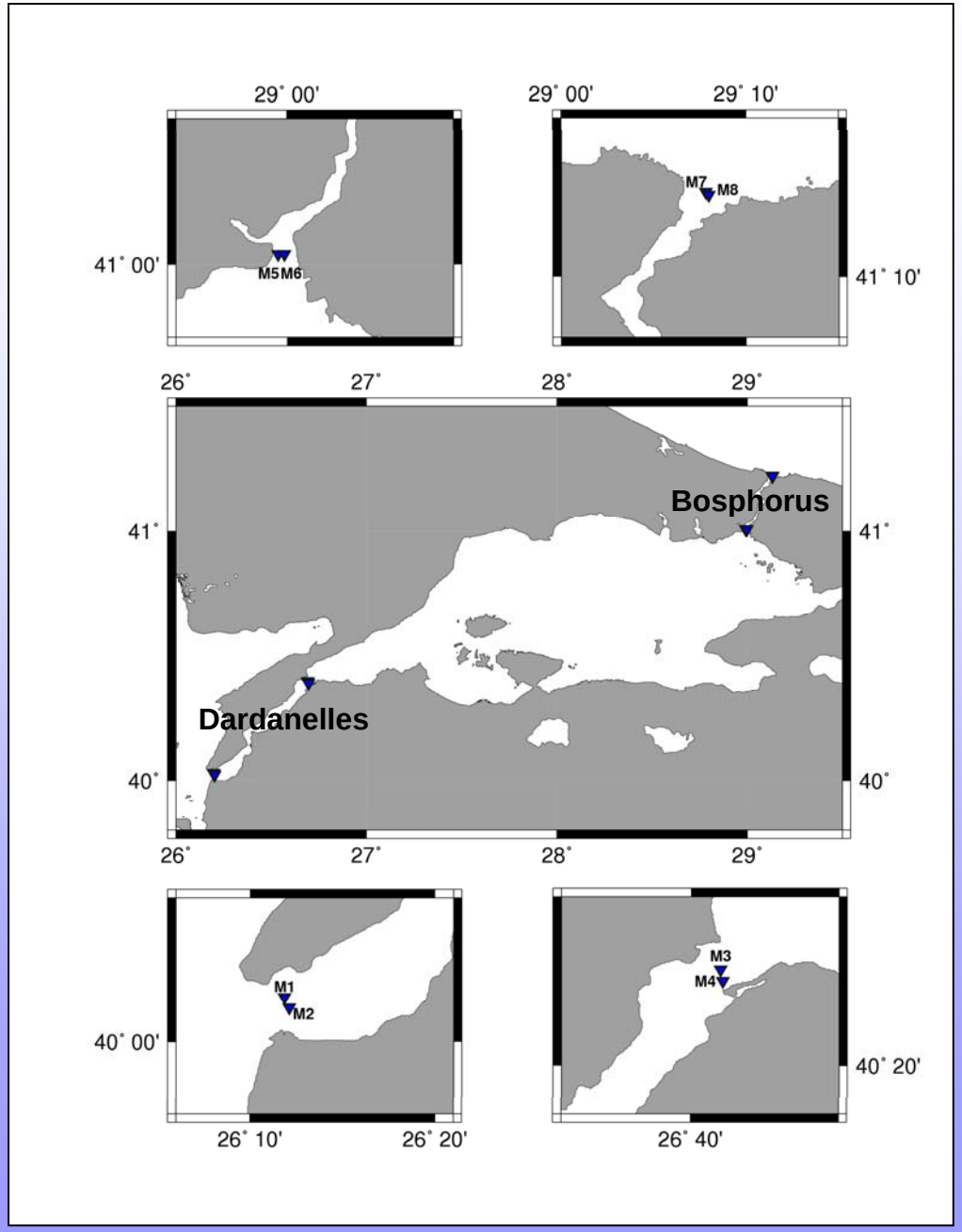


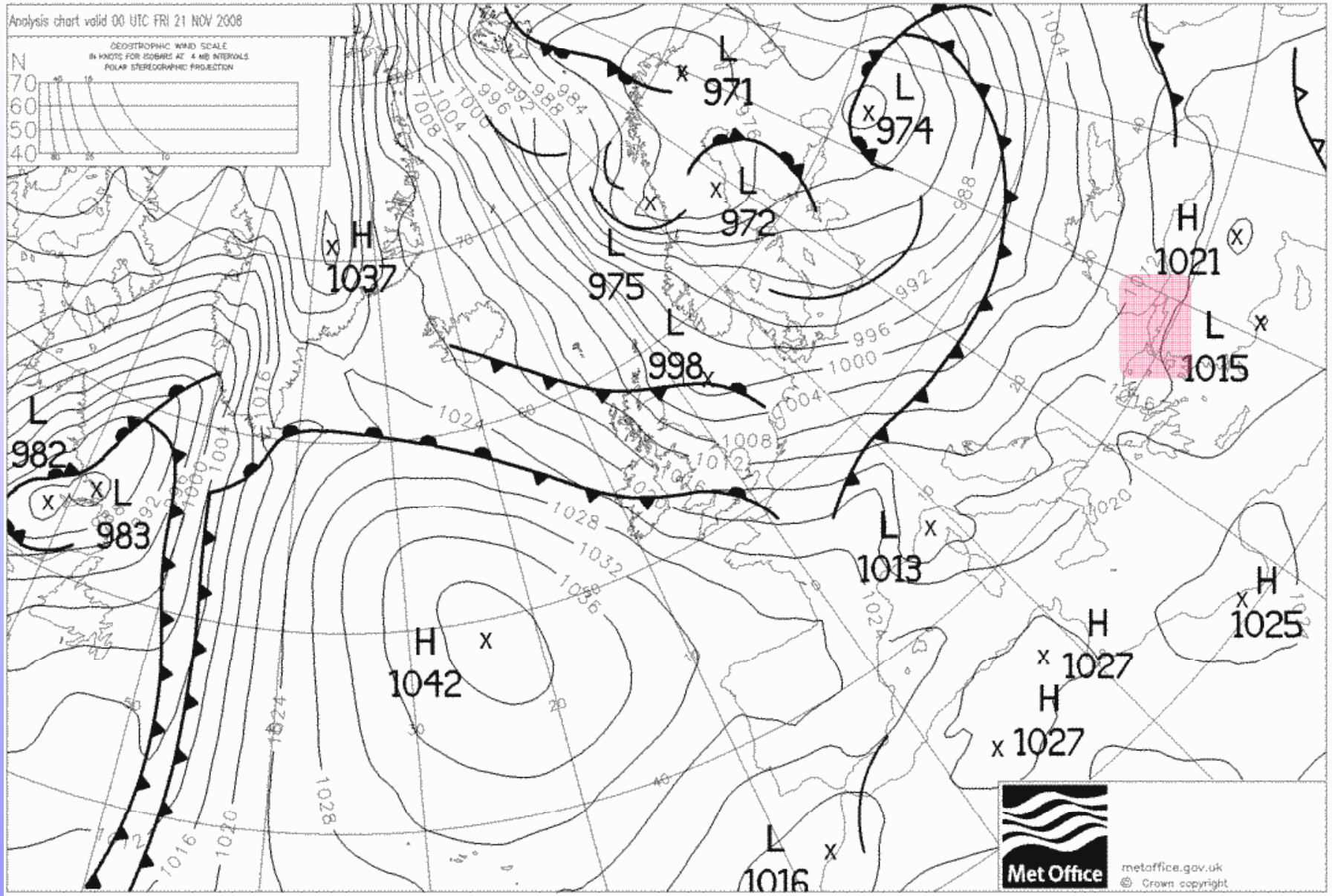


Turkish Straits Observations

- Collaborative Team
  - U.S. Naval Research Laboratory
  - NATO Undersea Research Centre
  - Turkish Navy Office of Navigation, Hydrography, and Oceanography
- 8 Acoustic Doppler Current Profilers (ADCP)
  - Sep. 2008 – Feb. 2009
  - pairs at entrances/exits
- Bottom Pressure
- Temperature/Conductivity line mooring for each section



00 UTC 21 November, 2008



Courtesy of UK MetOffice

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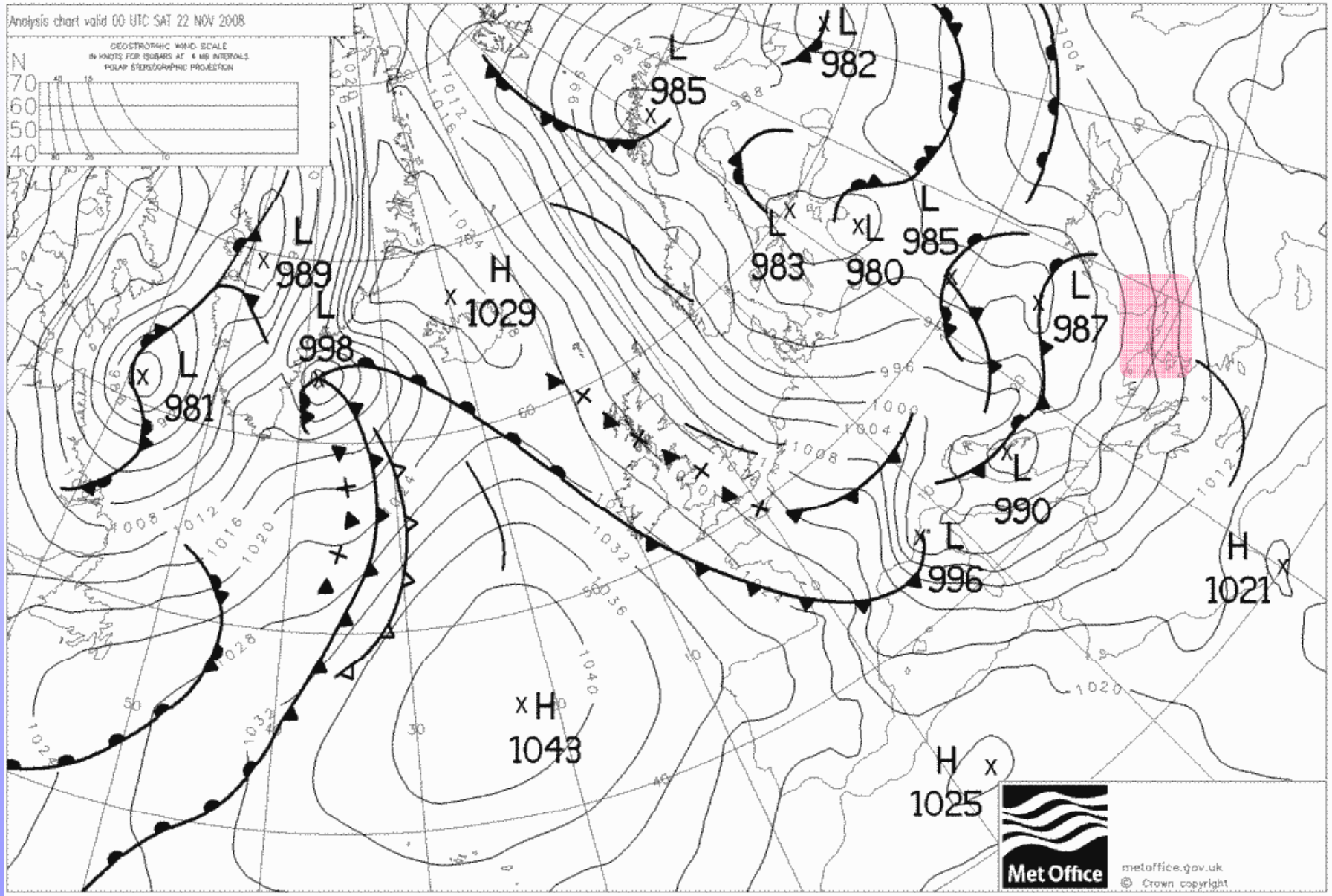

Courtesy of UK MetOffice

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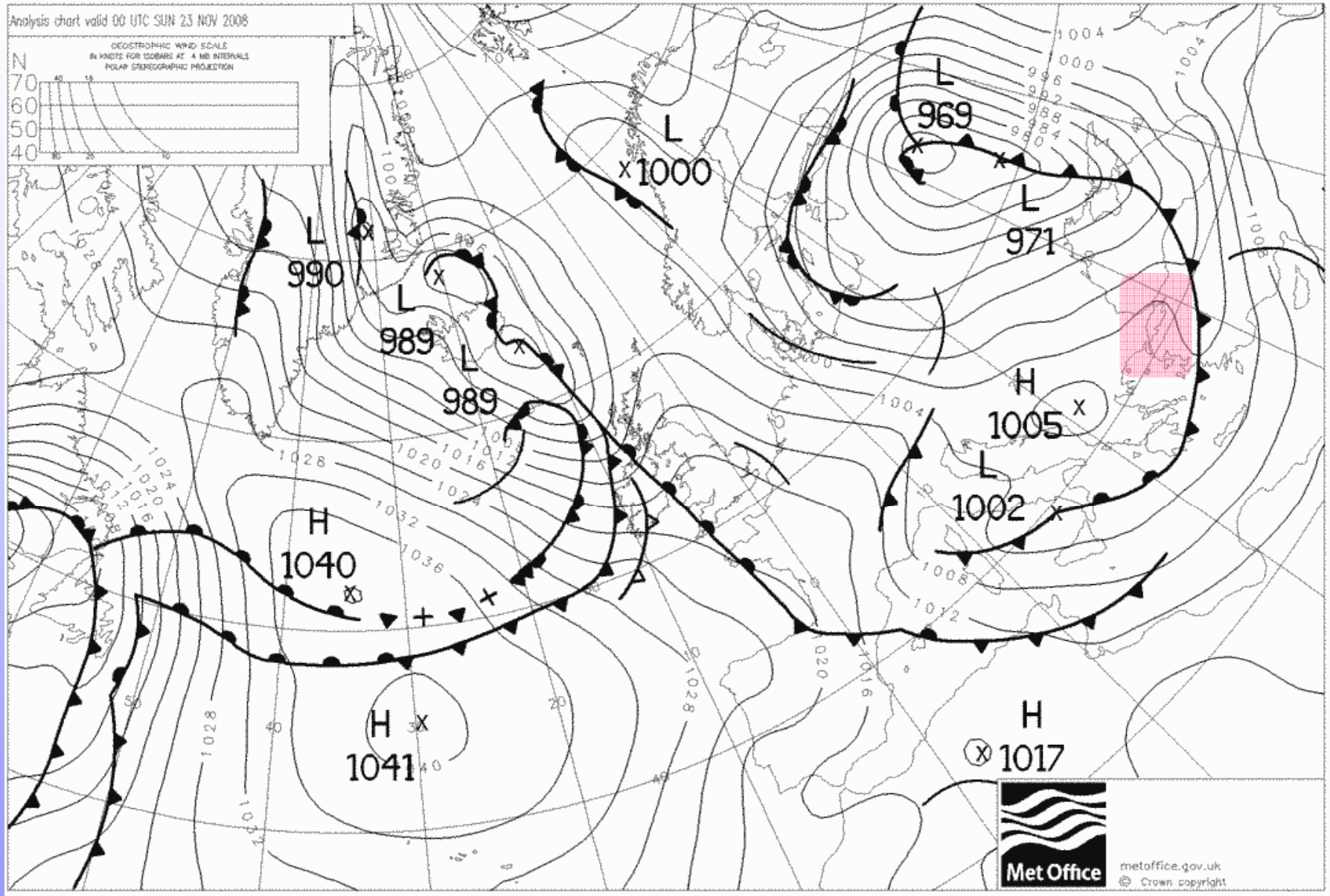

Courtesy of UK MetOffice

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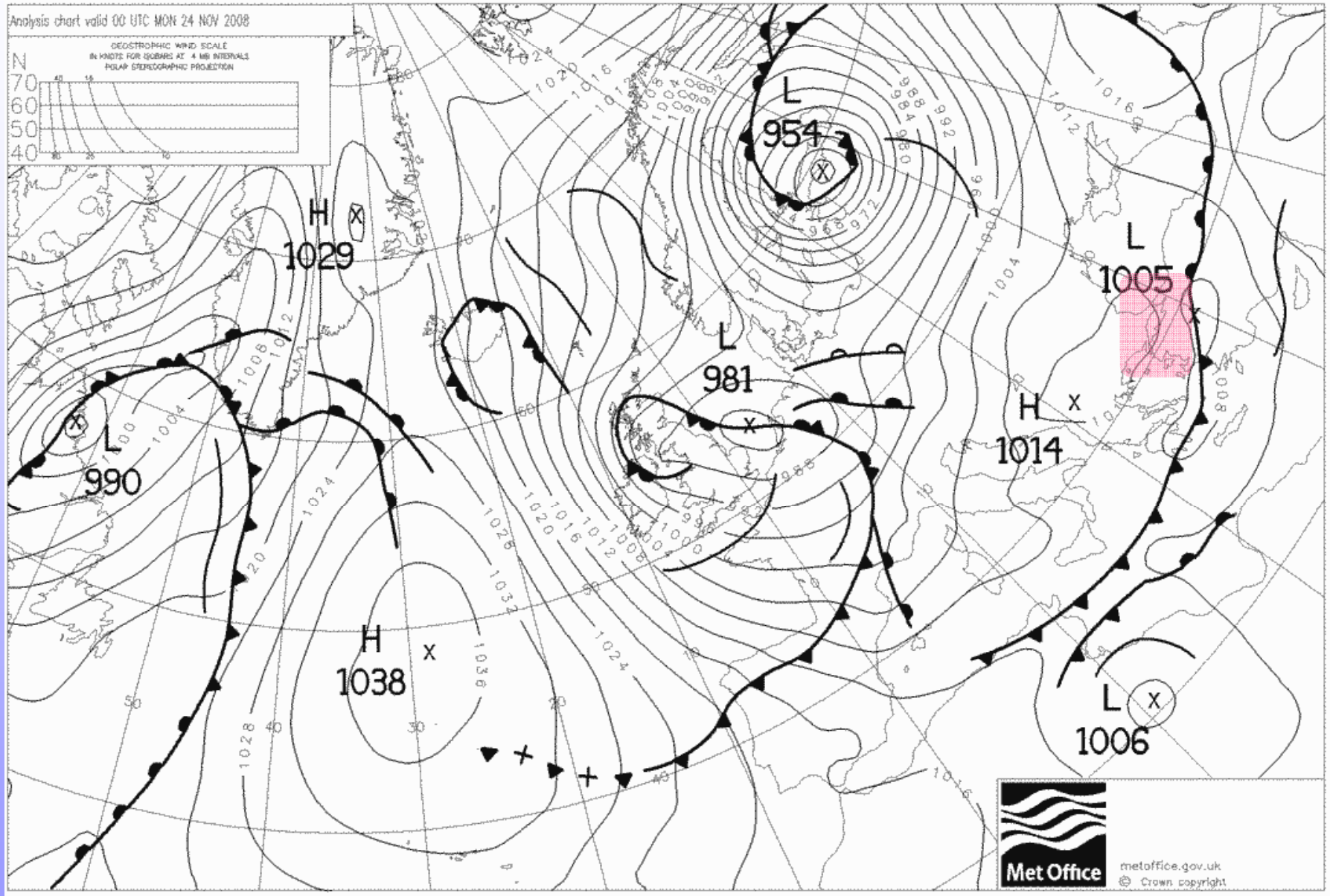
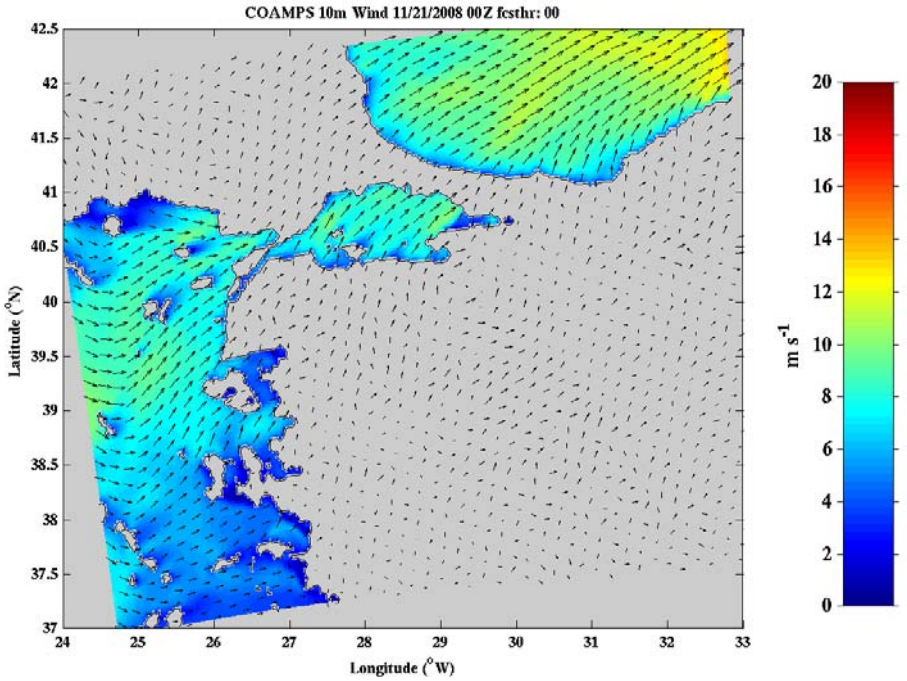


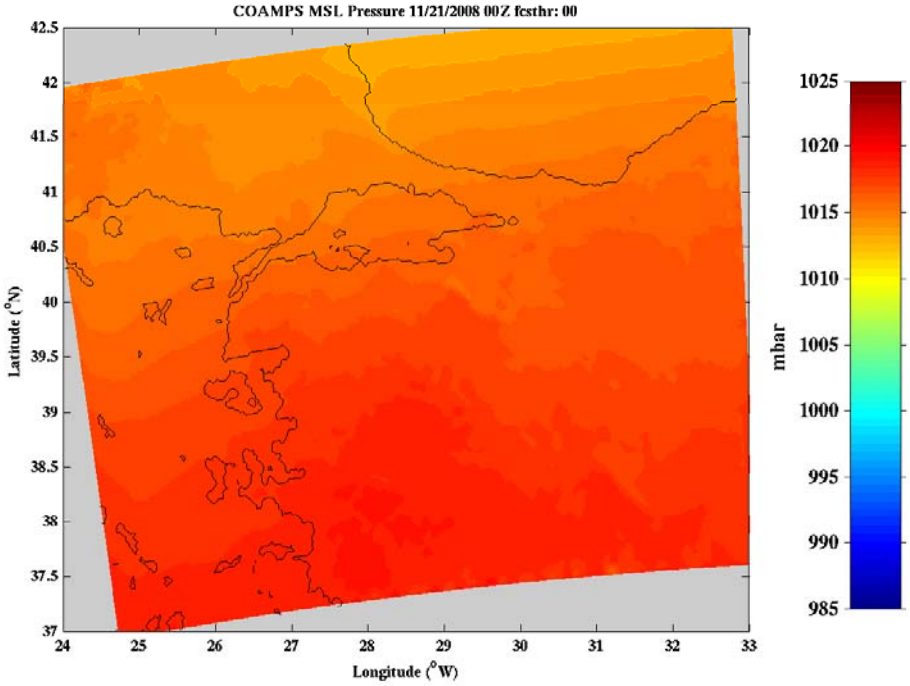
Courtesy of UK MetOffice

COAMPS simulations 3-km resolution

US Navy's COAMPS 27-9-3-km nested atmospheric model system



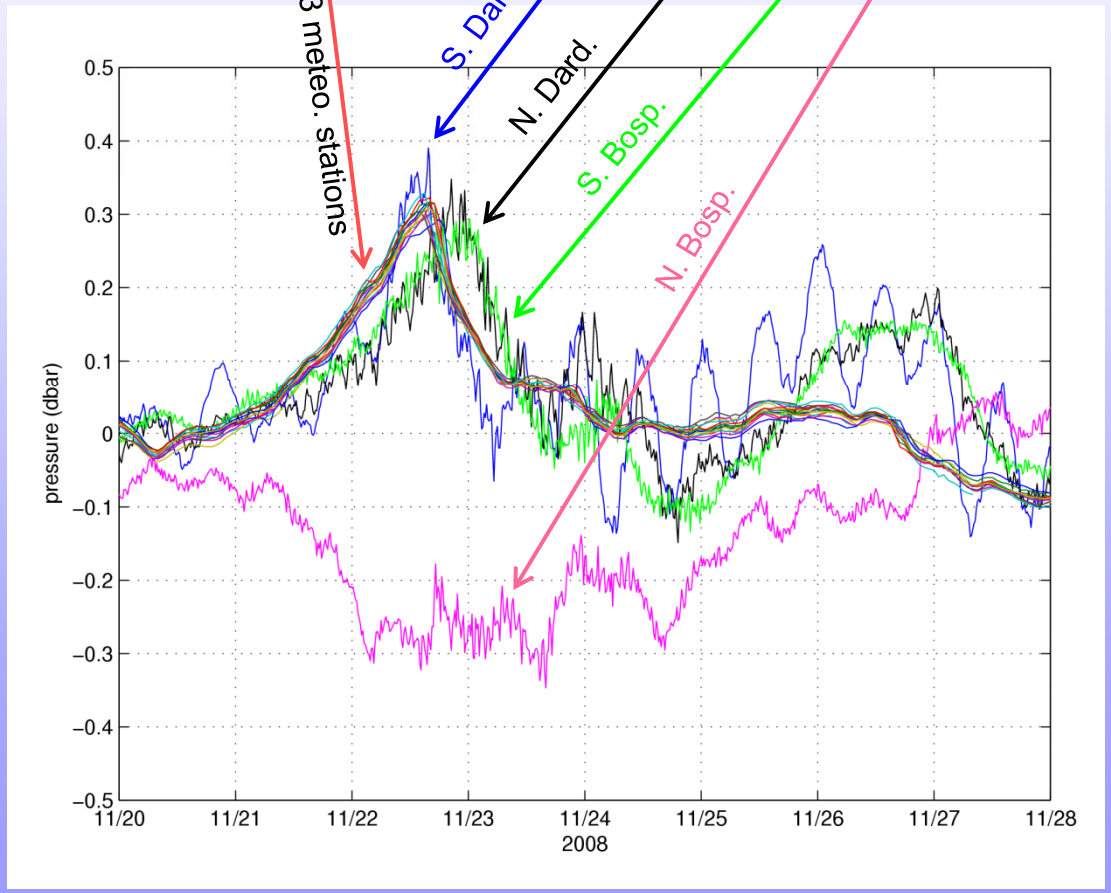
atmospheric pressure

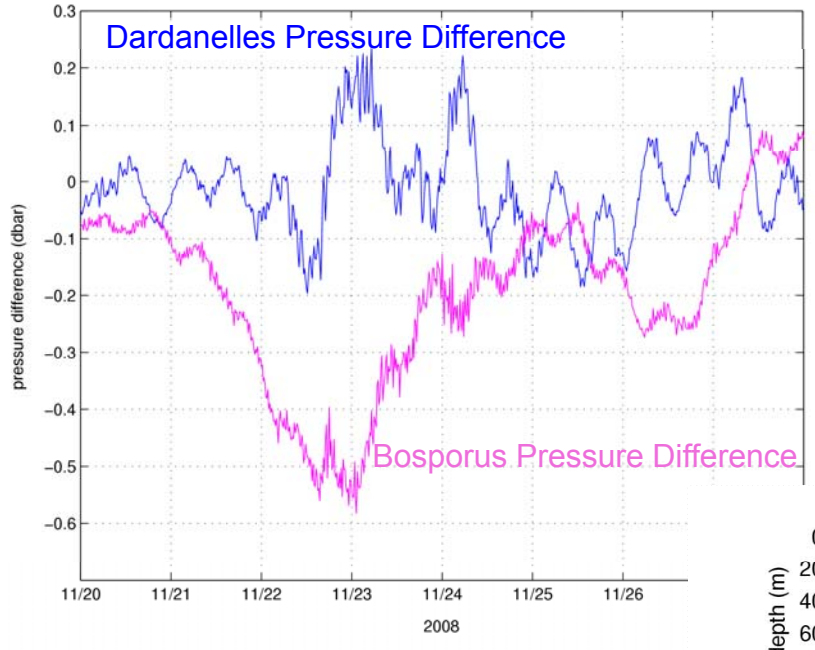


winds

Observed Bottom Pressure Anomalies

$$p_B' - p_{Atm}' = \rho_0 g \eta' + g \int_{-H}^{0} \rho' dz$$



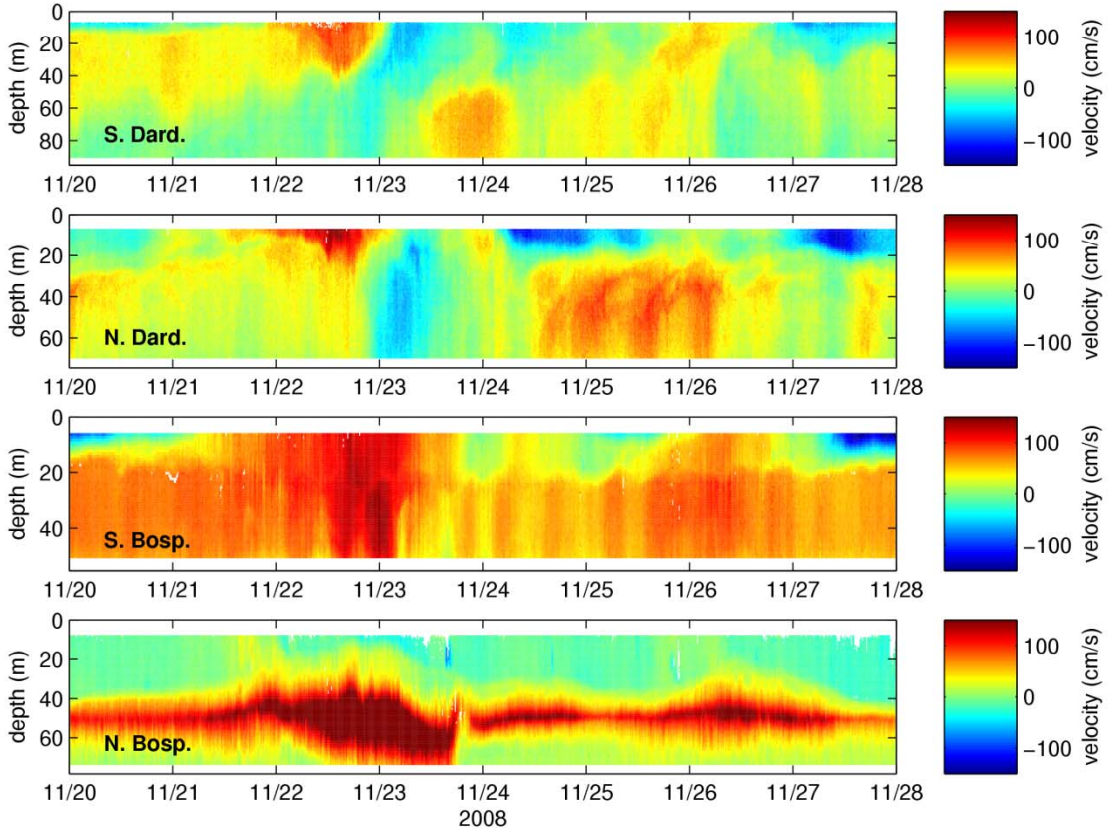


Bottom Pressure Differences

$$\Delta p_B' = \cancel{\Delta p_{Atm}'}^{\,0} + \rho_0 g \Delta \eta' + g \int_{-H}^{0} \Delta \rho' dz$$

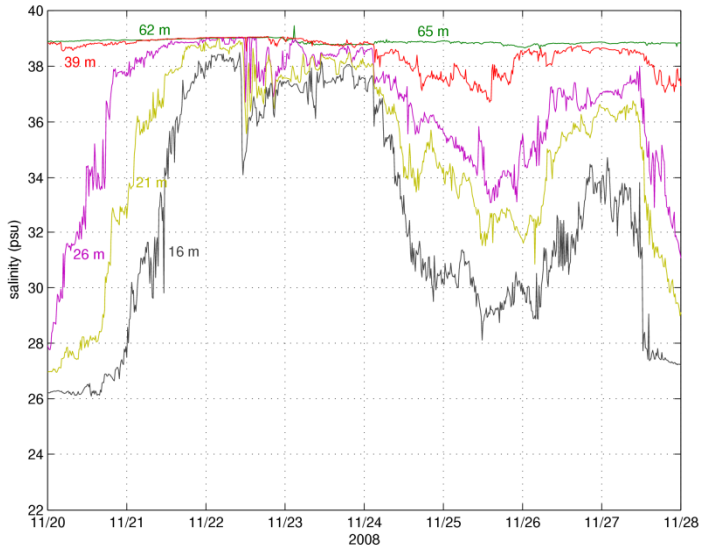
Along-Strait Velocities

- Reversal of upper layer in Dard. And S. Bosp.
- Strong Bosp. flow towards Black Sea
- Dard. Lower layer reversal 1 day later

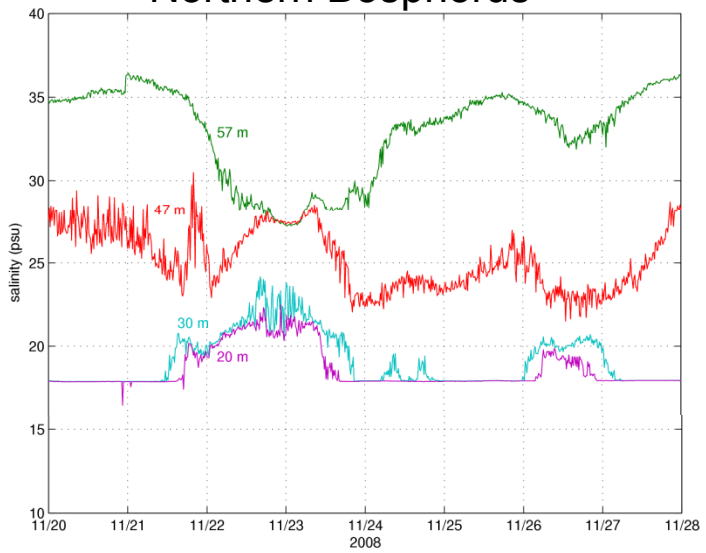


Observed Thermohaline Anomalies

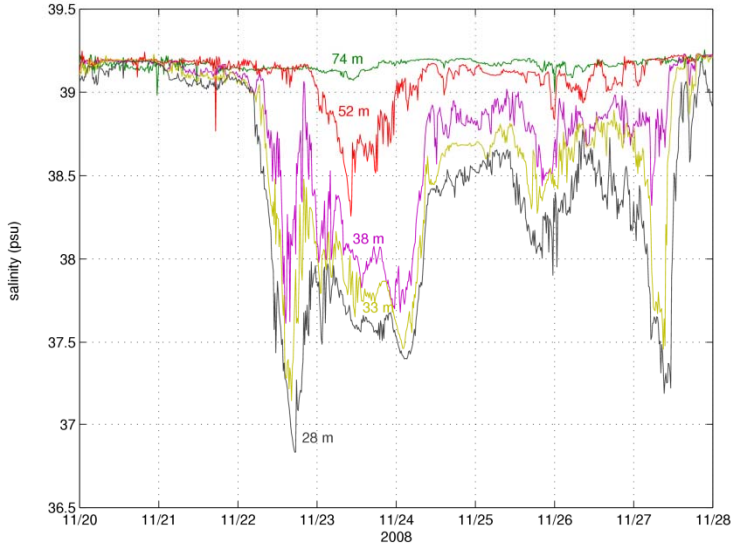
Northern Dardanelles



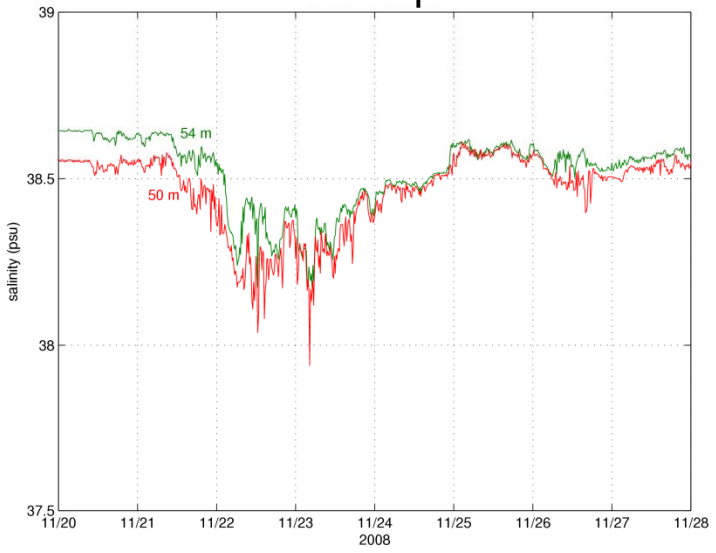
Northern Bosphorus



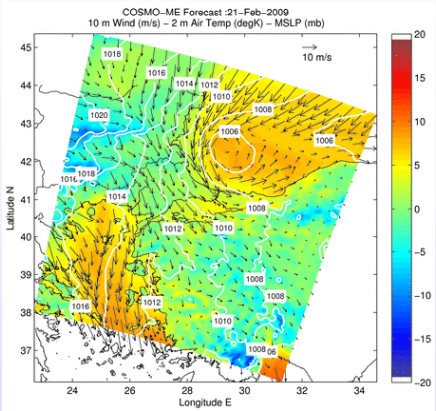
Southern Dardanelles



Southern Bosphorus



TSS ROMS System

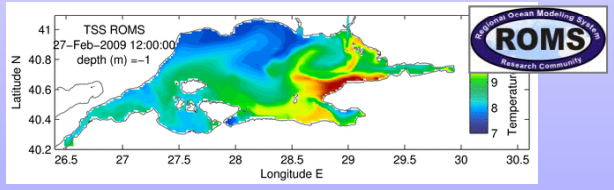


COSMO-ME atmospheric forcing
- wind 10 m
- mean sea level pressure
- air temperature 2 m
- dew temperature 2 m
- total cloud cover
- net short-wave radiation

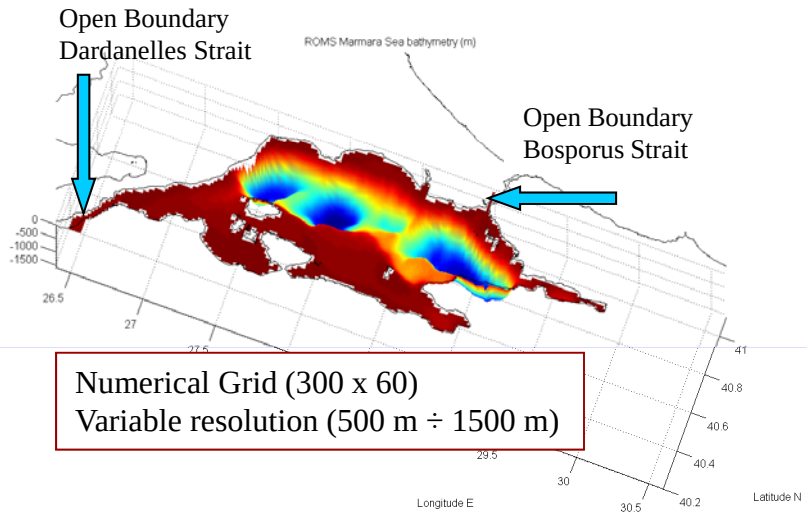
Atmospheric Model COSMO

1 way asynchronous coupling

Ocean Model ROMS



- initialized Aug. 2008 based on cruise CTDs
- Meteorological forcing by operational forecasts of the non-hydrostatic, 7 km horizontal resolution, limited area model COSMO (courtesy of Italian Airforce), ROMS computes heat fluxes and momentum stress via COARE 3.0 formula using its own SST.

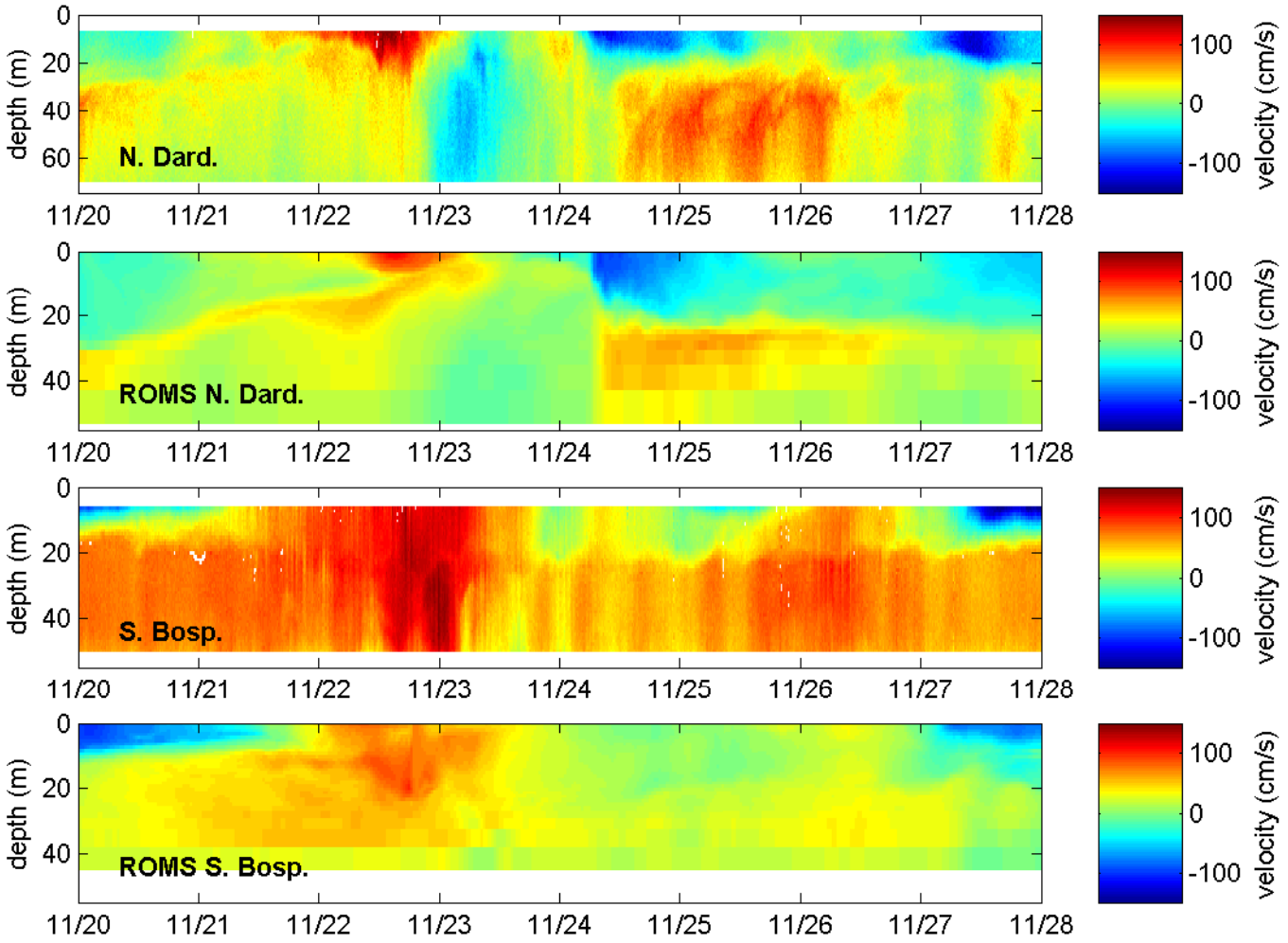


Numerical Grid (300 x 60)
Variable resolution (500 m ÷ 1500 m)

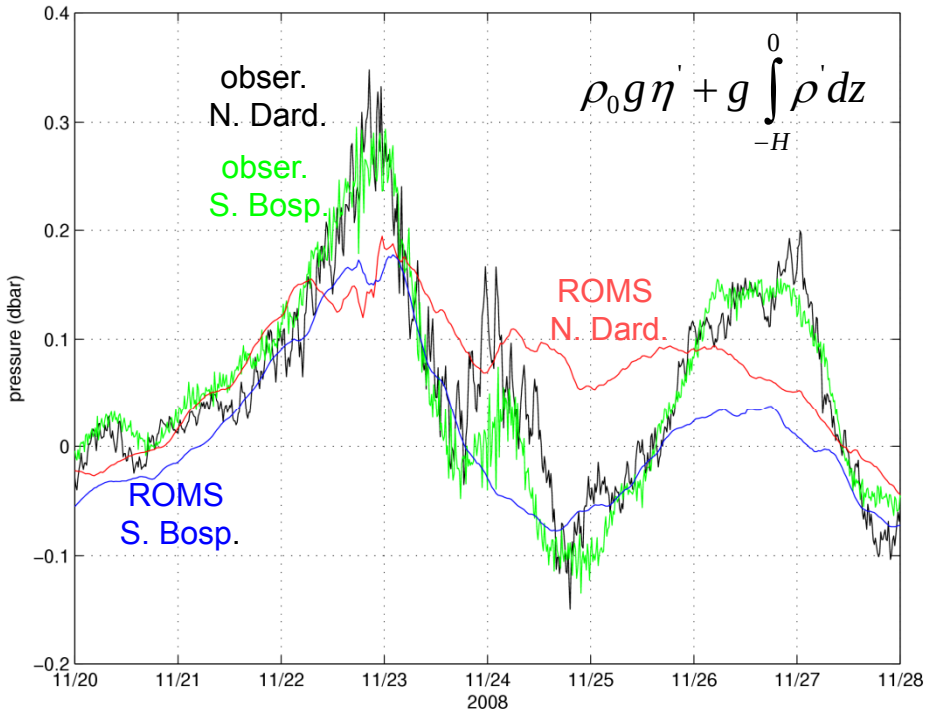
Open Boundaries (Straits)

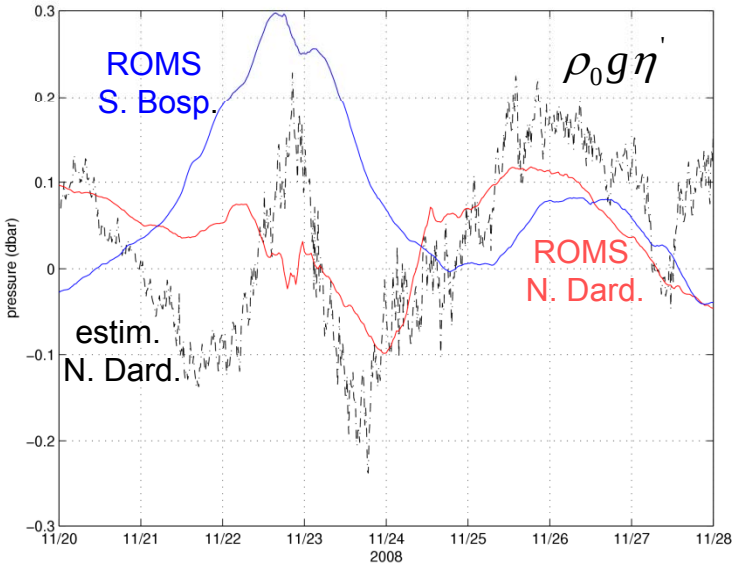
- Daily averaged volume fluxes (Flather (1976) condition).
- Climatological data are used for missing temperature and salinity measurements (upper layers)
- nudging to 40-hr low-pass filtered NRL ADCPs and T/C moorings data, baroclinic relaxation timescale of 1-3 days

ROMS velocities compared to observations

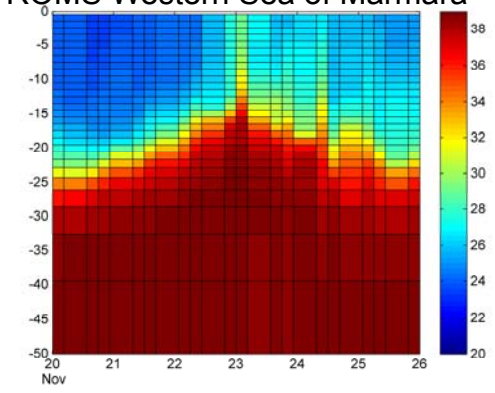


ROMS pressure reactions

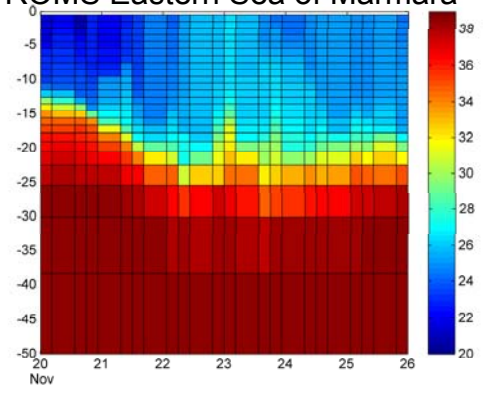


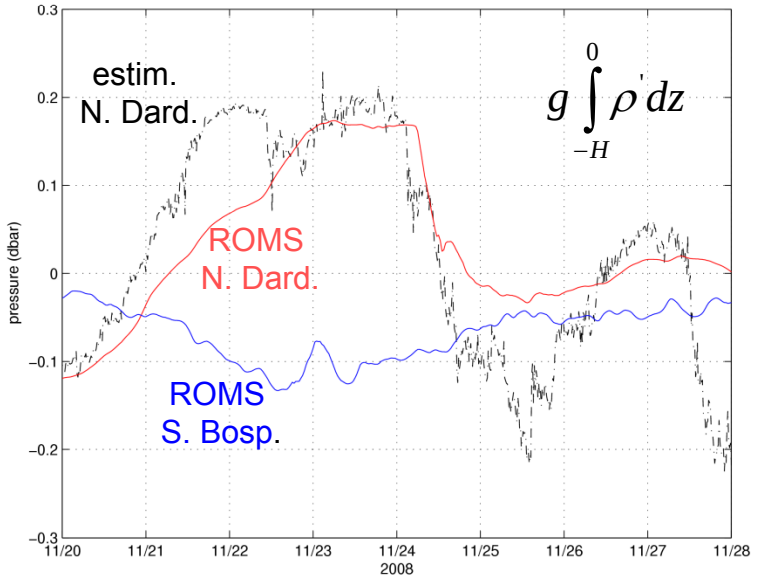


ROMS Western Sea of Marmara



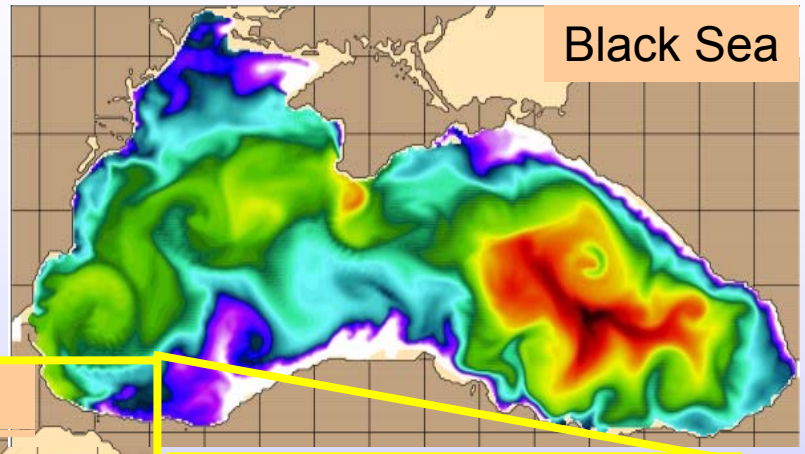
ROMS Eastern Sea of Marmara



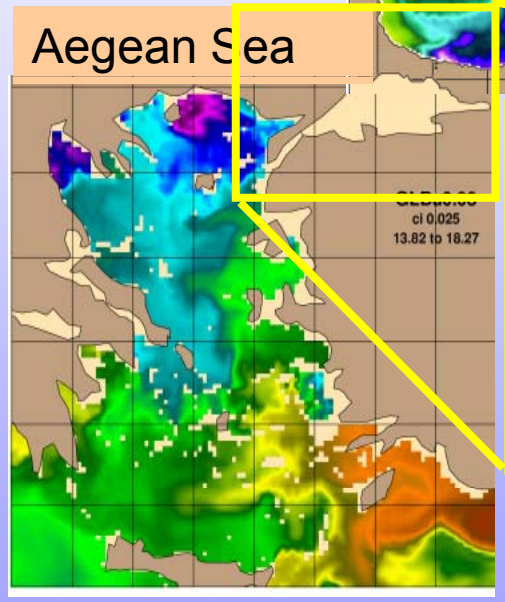


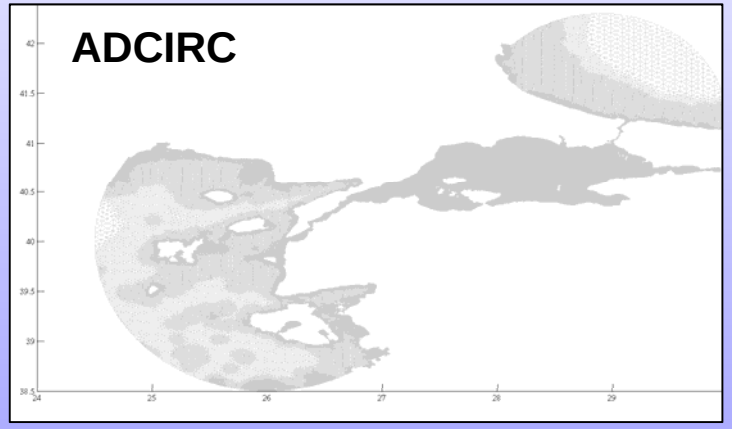
TSS ADCIRC System

HYCOM AMB
1.1 km resolution
Artificially opened Bosporus and Dardanelles Straits



TSS-ADCIRC mesh:
Size: 310435 nodes, 605099 elements
Resolution: 7.2 m minimum, 6.3 km maximum edge length





Atmospheric forcing of ADCIRC is from 3-km COAMPS simulations

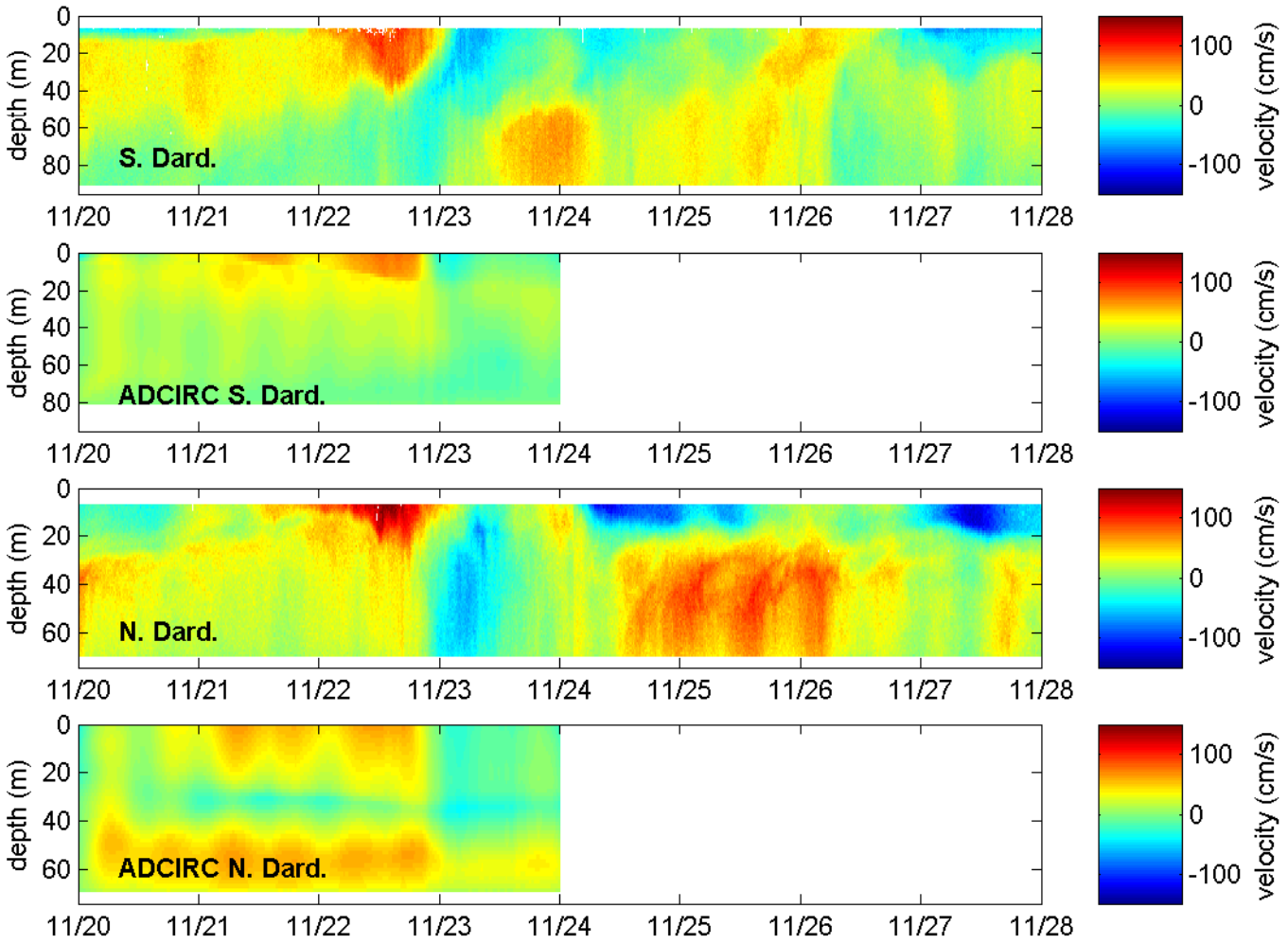
ADCIRC Turkish Straits Model

Unstructured, finite element mesh of variable resolution

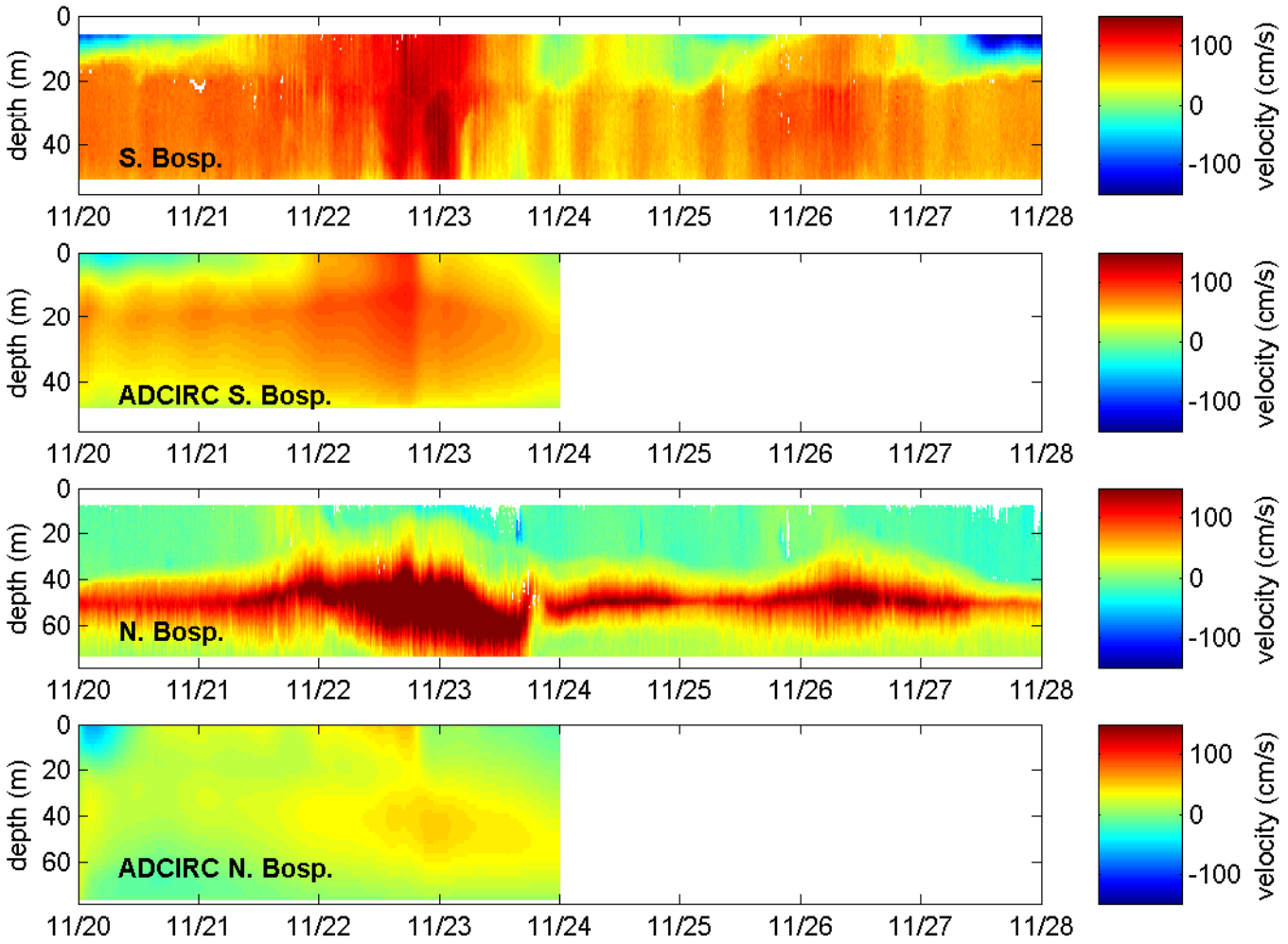
Connected basins and straits

One-way coupled to regional model

Preliminary ADCIRC comparisons to observations



Preliminary ADCIRC comparisons to observations



Conclusions

- The Turkish Strait System responds in a complex way to the "**meteorological bomb**" pressure change of Nov. 22-23, 2008

- The **Aegean Sea adjusts as an inverted barometer**, but neither the Marmara Sea nor the Black Sea can adjust quickly enough to follow an inverted barometer for this storm.

- Thus the difference in **inverted barometer** effect between the Aegean and the Marmara **drives a flow through the Dardanelles**

- The **Bosphorus** is relatively unaffected by the direct atmospheric pressure change, but is **driven by a deep low in bottom pressure** that develops in the **Black Sea**

- ROMS simulates some features of the events very well, but other features less well
    - Some differences can be attributed to **mixing high-resolution and smoothed forcing** of the simulations
- Analysis is ongoing: wind effects, ADCIRC simulations, etc.